

CHAPTER 3

SITE SELECTION

3-1. General.

a. Aerial imagery. The general remoteness and undeveloped nature of much of the world's arctic and subarctic regions pose special problems in acquiring adequate terrain information to plan and design both civil and military projects in these areas. Aerial imagery acquisition and analysis is a valuable tool for organizing and implementing a site selection process at the early stages of construction planning.

b. Imagery analysis. The procedures developed to analyze terrain through the use of aerial imagery are, in effect, processes of terrain evaluation and elimination. Starting with a reconnaissance overview of a large area using satellite imagery, many areas can be eliminated from further consideration because of topographic, drainage and access problems. Conversely, potential sites can be identified. From these possibilities, the best potential sites can be selected for a more detailed, refined analysis using stereoscopic aerial photography. Ultimately, a detailed data base of terrain information can be developed for a ground sampling program and for the placement of specific structures.

3-2. Regional analysis procedures using satellite imagery.

a. General. The military services of the United States have access to a vast array of satellite-acquired imagery through agencies within the Department of Defense. However, the images produced by these systems are classified, and the use or potential use of these materials will not be addressed in this manual. Instead, the unclassified, easily obtainable imagery products of the NASA/Landsat satellite program, under the direction of the National Oceanic and Atmospheric Administration (NOAA) and formerly under the United States Geological Survey (USGS), will be discussed in this manual.

(1) Digital data from the Landsat Multispectral Scanner Subsystem (MSS) sensor have been available for evaluation by the user community since July 1972. The MSS is a line-scanning device that obtains data for an area of 13,225 square miles (115 miles on a side) at a resolution of approximately 1.1 acres. Data are obtained in four spectral bands — two in the visible (0.5 to 0.6 μm [micrometers = microns] and 0.6 to 0.7 μm) and two in the near infrared (0.7 to 0.8 μm and 0.8 to 1.1 μm).

(2) In the 1982 the Thematic Mapper (TM) sensor was launched on Landsat 4. The Thematic Mapper sensor is a mechanical line scanner device, similar to the MSS. However, it scans and obtains data for six scan lines in both directions during the scanner sweep. The MSS only scans and obtains data in one direction for six scan lines at a time. The TM acquires data at a resolution of approximately 0.22 acres for seven spectral bands ranging from the blue part of the spectrum into the spectrum into the thermal infrared region (0.45 to 0.52 μm , 0.52 to 0.60 μm , 0.63 to 0.69 μm , 0.76 to 0.90 μm , 1.55 to 1.75 μm , 2.08 to 2.35 μm , and 10.4 to 12.5 μm at approximately 400 feet).

(3) In February 1986, the French launched the Systeme Probatoire d'Observation de la Terre (SPOT) satellite. This operational satellite is in a near-polar orbit, similar to the Landsat satellites. There are two High Resolution Visible (HRV) sensors on SPOT. The instrument is also point-able, imaging 26 degrees on either side of nadir. There are two modes of instrument operation—the multispectral and panchromatic.

(4) The multispectral mode covers three spectral regions—two in the visible (0.50 to 0.59 μm , 0.61 to 0.68 μm) and one in the near infrared (0.79 to 0.89 μm) at a resolution of approximately 0.1 acres. The panchromatic (black and white) mode covers a wide band ranging from 0.51 to 0.73 μm at a resolution of approximately 0.025 acres. When the satellite is pointed at nadir, both HRVs image 37-mile wide areas. The satellite can point off to either side of nadir at 0.6-degree increments, up to 26 degrees on either side of the orbital path. The satellite can thus image any area within a 589-mile swath centered over the orbital path. This allows for acquisition of stereo imagery and for more revisit opportunities over an area of interest. A maximum of six stereo-pairs can also be obtained during the 26-day cycle.

(5) The satellite data are acquired in a digital mode from the MSS, TM and HRV sensor systems and can thus be analyzed by a computer. The geometric accuracy of the data is to within one-half of a pixel. With this accuracy, the digital data from the sensor systems can be referenced to any coordinate system.

b. Obtaining Landsat images. Reproductions of Landsat imagery can be obtained from the Earth Observation Satellite Company (EOSAT), 4300 Forbes Blvd., Lanham, MD 20706. A computer

listing of available images will be sent along with an order form and a key to explain the information in the listing. The computer listing will identify all images and photographs available over *op* close to an area of interest. Each image or photograph will be described in two printed lines on the computer listing. A number of entries may be listed, depending on the size of the area selected and the restrictions of the supplemental data. Imagery or photography may be available from more than one source (e.g., from Landsat, Skylab, NASA aircraft, or aircraft of the U.S. Geological Survey or other agencies) all of which differ significantly in sensor or camera characteristics. Thus, each entry on the computer listing should be carefully studied to determine the best selection for the purposes under consideration. The first line of each entry on the computer listing gives data characteristics, along with information required for subsequent ordering. The second line of information denotes the geographic coordinates (by latitude and longitude) of each individual image.

c. *Method of using Landsat images.* Landsat images provide an ideal basis for conducting a regional terrain analysis of an area of interest. To demonstrate the use of these products, a hypothetical terrain analysis for site selection has been conducted and is portrayed in the series of illustrations that follow. Based on the computer search for a suitable Landsat image, the four bands of imagery of an area of Alaskan terrain were ordered and appear as figure 3-1. The false color composite (shown in black and white in fig. 3-2) was formed by the superpositioning of bands 4, 5 and 7 through corresponding filtration. When available, the false color composite should be ordered for site selection; otherwise, either bands 5 or 7 would be usable.

(1) The Landsat series of images do not produce stereoscopic images. There is only about 10% endlap between frames. At high latitudes where orbital paths converge at the pole, sidelap stereo can be observed between images of adjacent orbits. However, because of the high altitude at which these images have been obtained, only large, mountainous features tend to express much sense of topographic relief. The primary use of these Landsat images for analyzing terrain is to conduct a monoscopic (not stereoscopic) pattern analysis.

(2) The overlay presented as figure 3-3 is a result of a monoscopic pattern analysis of the false color composite Landsat image (fig. 3-2). The legend briefly describes the categories of terrain information derived by analyzing patterns on the Landsat scene. Much of the area consists of terrain

features that are normally unsuitable for building sites, such as areas of high elevations (mountainous terrain), or thermally unstable and sensitive areas (thaw lakes and permafrost zones). By considering the large river that traverses the scene as a possible way to get into the area, an area of interest to be studied in greater detail was selected. This area is enclosed in the rectangle on the overlay. Of particular interest was the river, its broad floodplain, and the dissected terrace area, which might be suitable for a construction site. Therefore, based on a monoscopic pattern analysis of a large area (approximately 13,225 square miles), involving the delineation of photo patterns associated with topography, drainage and permafrost conditions, an area was selected for further, more detailed study (with aerial photography). The selection should be based on the scale and scope of the project.

3-3. Localized area analysis procedures.

a. *Obtaining existing stereoscopic aerial photography.* While there still are areas in the earth's arctic and subarctic regions where no aerial photography has ever been acquired, it is more usual to find that there is adequate airphoto coverage of these regions. The primary reason for photographing these remote areas in the first place was to produce maps. More recently, the exploration for natural resources in arctic and subarctic areas has led to even more aerial photography coverage. Aerial photography aimed at mineral and other natural resource explorations has been, and is being, done by both governmental and private organizations for many of the countries bordering the Arctic. In the United States, for example, the U.S. Geological Survey, Bureau of Land Management, National Park Service, State of Alaska, and the Department of Transportation have flown aerial photography missions in Alaska, so have many major U.S. oil companies and the Alaska Pipeline Service Company (Alyeska). An increasing amount of aerial photography is being acquired for environmental research projects being done in arctic regions.

(1) In addition to these sources, the Defense Mapping Agency, the Defense Intelligence Agency, the U.S. Air Force and U.S. Navy periodically acquire aerial photography of arctic areas. Unfortunately, there is no one organization that keeps up to date on all the aerial photography produced in these regions. As far as the United States is concerned, the EROS Data Center of the USGS at

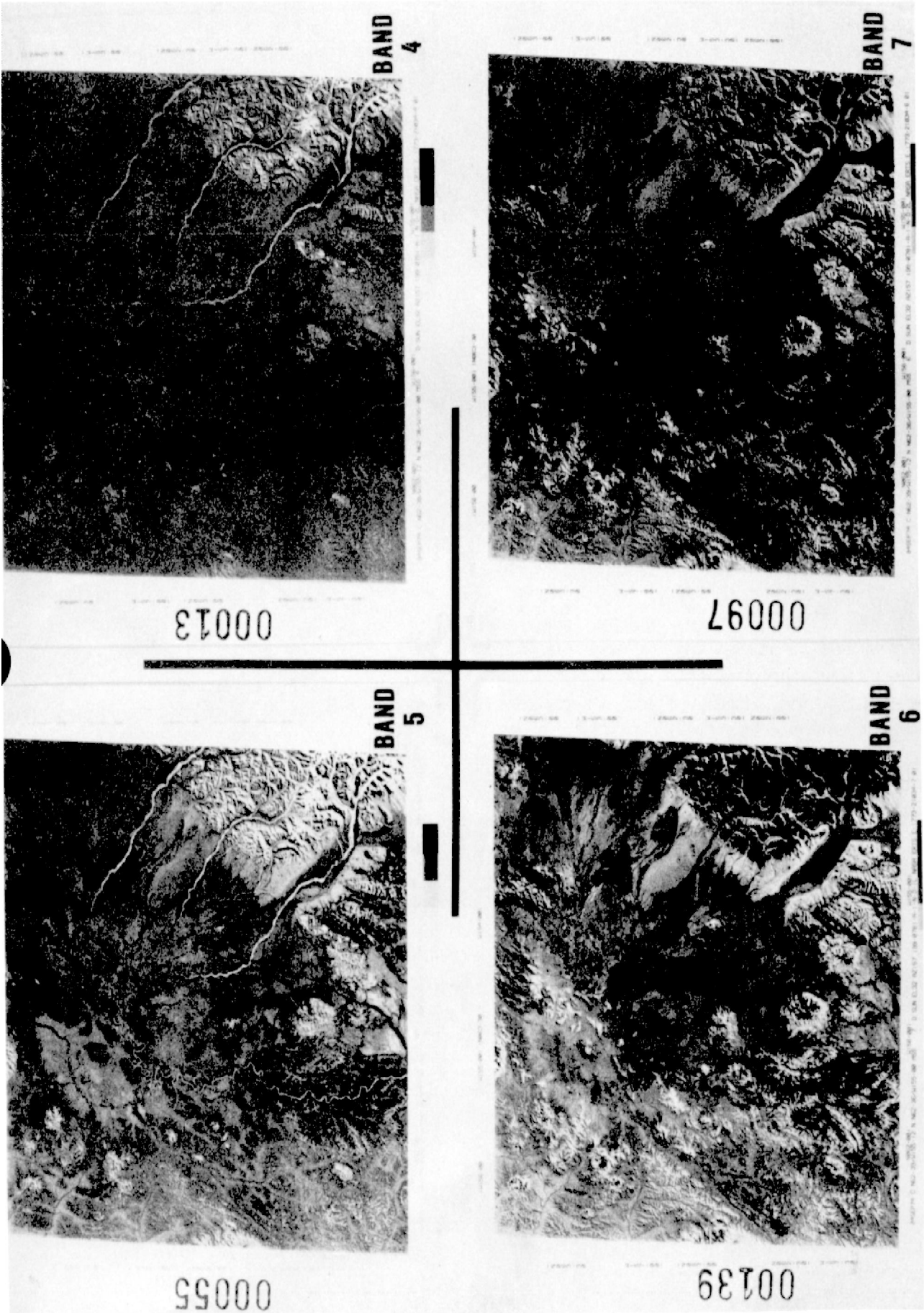


Figure 3-1. Four spectral bands of Landsat.

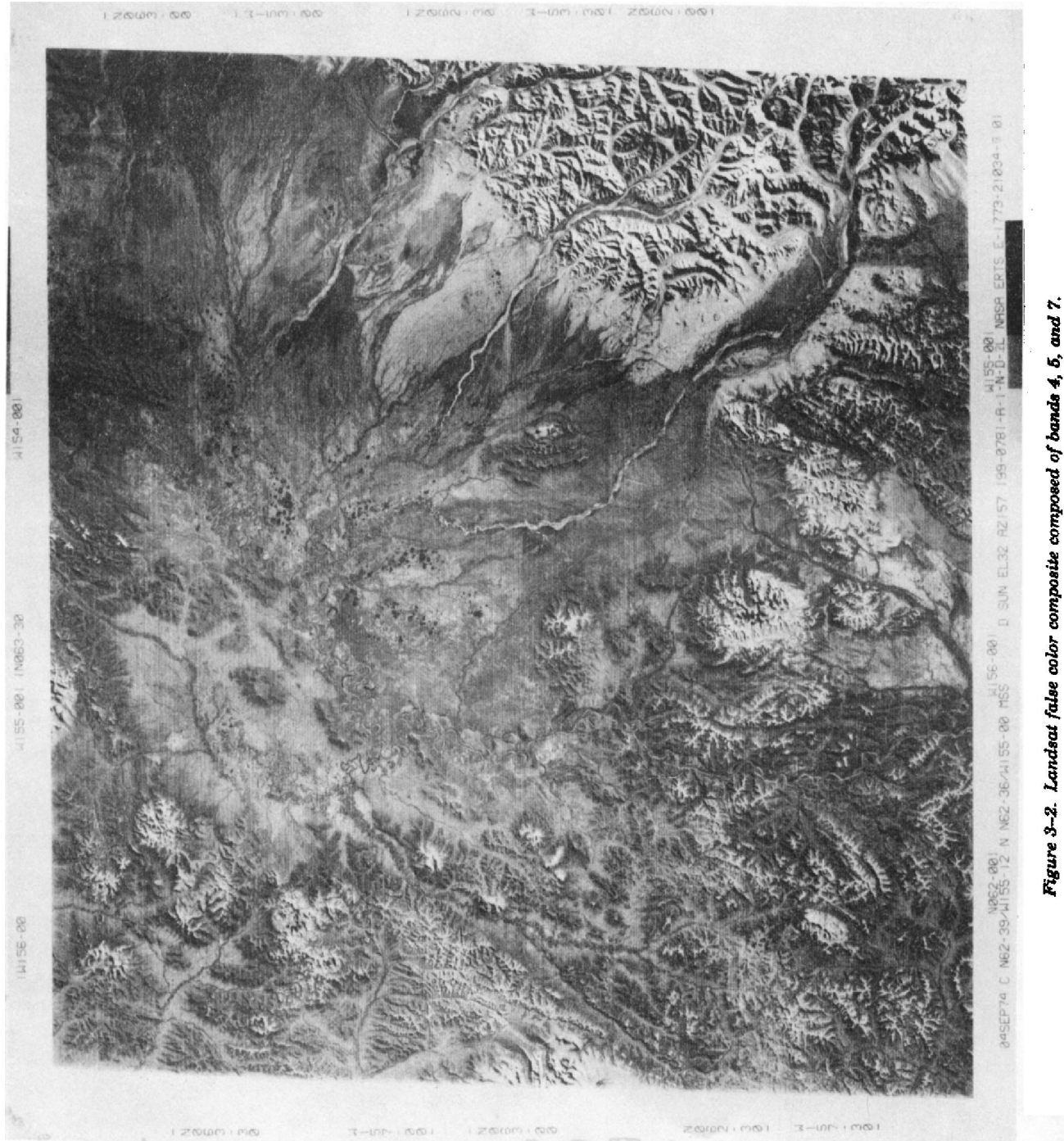
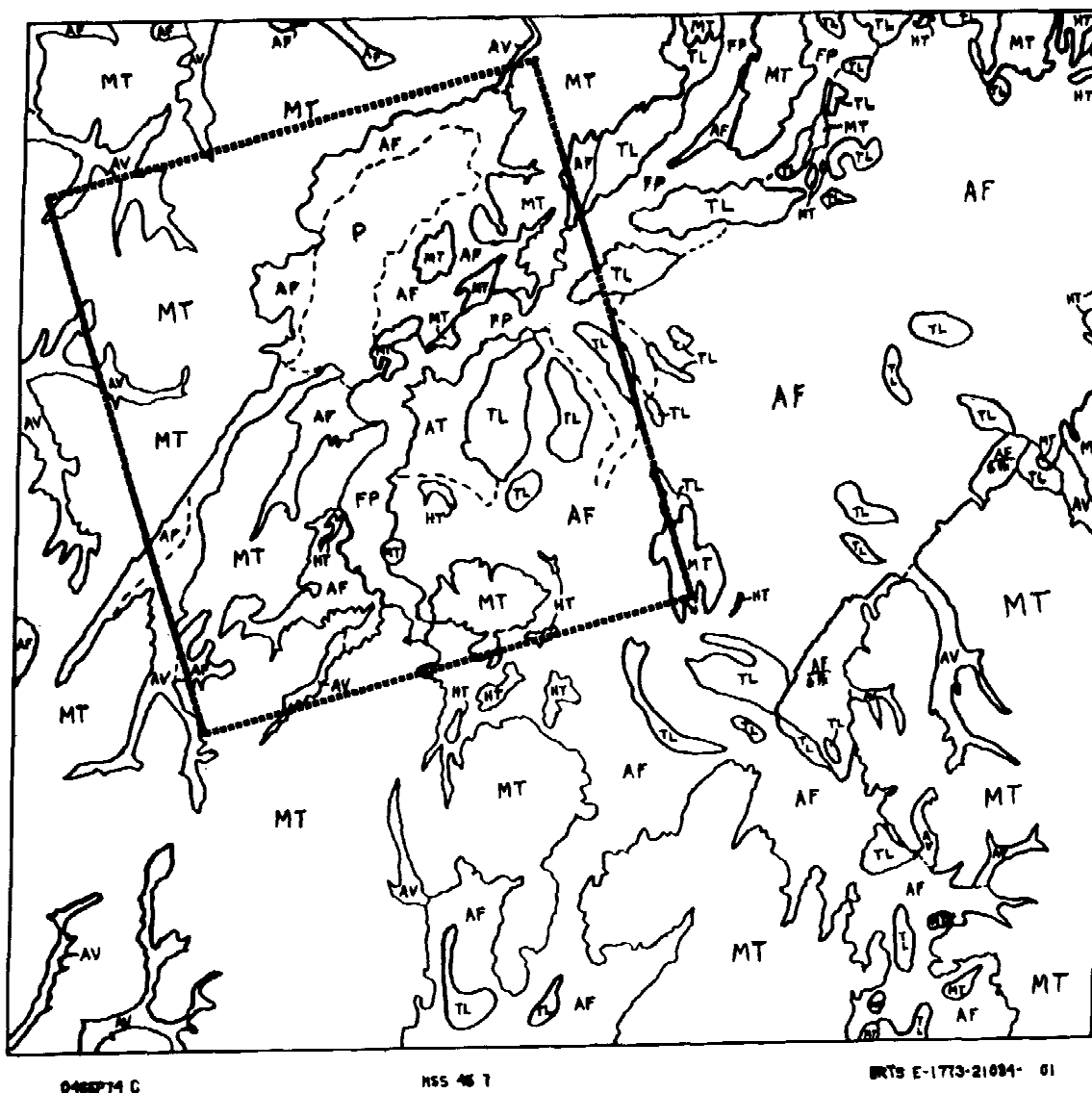


Figure 3-2. Landsat false color composite composed of bands 4, 5, and 7.



LEGEND

— Well-defined Boundary	AF/SRx Alluvial Fans Over Shallow Rock
- - - Indistinct Boundary	AV Alluvial Valleys
MT Mountainous Terrain	P Permafrost Indications
HT Hilly Terrain	TL Thaw Lakes
AT Alluvial Terrace	FP Flood Plain
AF Alluvial Fans	■ ■ ■ Detailed Study Area

Figure 3-3. Terrain analysis overlay to Landsat false color composite image.

Sioux Falls, South Dakota, probably contains the most comprehensive inventory of aerial imagery in its data bank.

(2) A number of techniques are used to indicate and identify what particular aerial photograph covers what particular area. A common method used by the USAF and a number of other government, as well as commercial, agencies is the "flight line map." The centerlines of strips of aerial photography are drawn on a base map, with the photo mission, date, scale, emulsion and camera specifications usually annotated as part of the legend. Usually, the ends of each flight line are also annotated with film roll number and exposure number. By use of a flight line map that covers the area of interest, the exact exposure numbers can be identified to place an order for photographic prints.

(3) A second method uses a "photo index sheet" where all of the aerial photographs taken of an area have been roughly pieced together with all exposure numbers showing. This mosaic is photocopied and reduced to a convenient size (the U.S. Department of Agriculture uses a 20- by 24-inch size), which can be used to order the aerial photographs required.

(4) A third method, becoming more common, is conveying all aerial photography information through a computer printout. This method is parallel to the previously illustrated method of ordering and determining satellite imagery coverage. In this instance, a search is made by the EROS Data Center for specific airphoto coverage of an area based on geographic coordinates. Upon the completion of the search, a computer printout is received and the user can select his photo.

(5) To ascertain the coverage of certain photos listed on the printout, a rough flight line coverage overlay should be developed on a suitable base map. This process is illustrated in figure 3-4, where the data have been transposed into a photo coverage overlay based on a 1:250,000 topographic map. Since, in this case, the computer printout had indicated each corner covered by a strip of photography, the overlay has been constructed to show the total area covered by each flight line as well as all the flight lines needed to cover the desired area.

b. Acquisition of new aerial photography. Quite often it is desirable, and at times necessary, to acquire new aerial photography either to supplement existing photos or in case no suitable existing aerial photography can be obtained. In requesting new photography the following items should be considered.

(1) *Types of photographs.* Nine- by nine-inch

oblique and vertical photographs are most commonly used. Low-altitude obliques are useful for evaluation studies and illustration. Vertical stereopairs greatly aid terrain interpretation.

(2) *Focal length of lens.* A lens with a short focal length should be used in flat areas to increase the apparent depth perception in the stereoscopic image so that minute changes in relief are resolved. A 6-inch lens is recommended. In hilly or mountainous terrain, a 12-inch focal length lens is most practical.

(3) *Type of film.* Panchromatic (black and white) film is widely used for a basic photo coverage. Color aerial film and color infrared film are being increasingly used, especially over selected, environmentally sensitive areas. Color infrared film is normally used to produce positive transparencies rather than paper prints.

(4) *Types of filter.* Filters are used to cut atmospheric haze and to accentuate tonal differences. Yellow haze filters, often referred to as "minus blue" filters, are used with both panchromatic and black and white infrared films.

(5) *Overlap and sidelap.* Photography intended for use in mosaics and for detailed stereoscopic interpretation should have a 60 percent overlap between frames along a flight line and a 30 percent sidelap between flight lines.

(6) *Location.* Geographical coordinates bounding the area should be indicated. Flight lines plotted on large-scale topographic maps are of considerable value to the aerial photographer. If possible, checkpoints should be established on the ground to aid the aerial photographer.

(7) *Scale.* The scale of photography is normally specified in terms of the representative fraction (RF), which is equal to the flying height (in feet) of the aircraft above mean terrain, divided by the focal length (in feet) of the aerial camera. For example, the scale of photography flown at 6,000 feet with a 6-inch lens is 1:12,000. For regional coverage and analysis, scales of 1:40,000 to 1:80,000 are recommended. For local, highly detailed analysis, scales as large as 1:10,000 to 1:20,000 are useful.

(8) *Season for photography.* Usually, the summer season in arctic areas is specified because of extended daylight and a lack of a snow cover in most areas.

(9) *Annotation of negatives.* Every aerial photograph should be annotated with at least an exposure number. Each end photo of a flight line should be annotated with roll number or line number, scale, and date. To adequately control numerous aerial photography projects, a project symbol should be annotated on each photo.

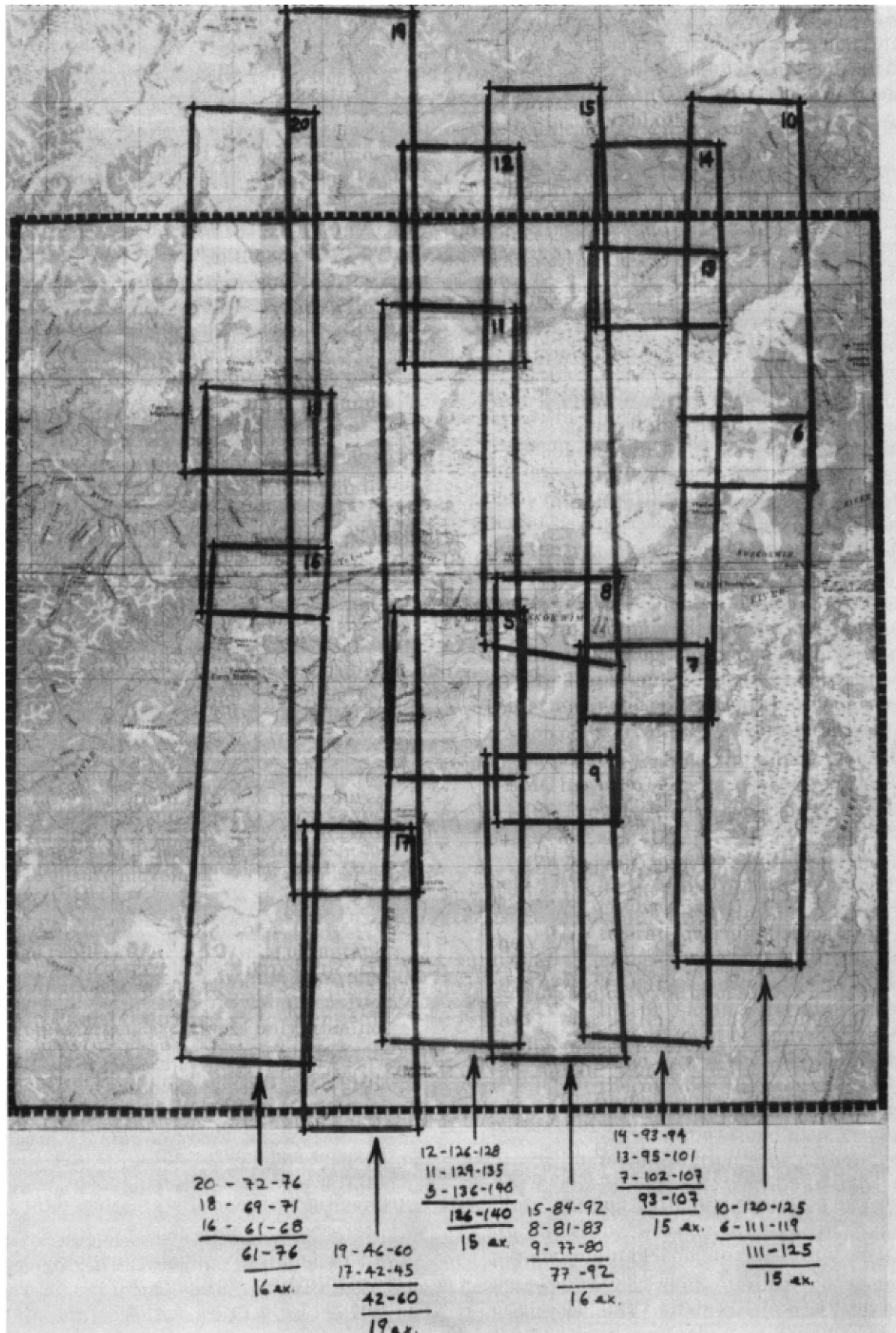


Figure 3-4. Photo flight line overlay to a 1:250,000 topographic base map.

(10) *Type of prints.* For most interpretation work, semi-matte finished (9- by 9-inch) contact prints on RC (resin coated) paper are advisable. The option to request enlargements from (9- by 9-inch) aerial negatives is available, if needed for planning.

(11) *Flight line map or photo indices.* It is very desirable to obtain or create a flight line map or a photo index map of the requested photo coverage.

c. Assembling the stereoscopic aerial photography data base. Upon receipt of the aerial photography, all of the photos must be trimmed to the edge of the actual image. In some instances, pertinent annotations regarding exposure number, scale, date, etc., are contained in these areas, which must be trimmed from the prints when the mosaic is prepared. At least the exposure numbers should be transferred inside the image boundary. An example of this supplementary annotation can be seen on some of the strips of photos on the stereomosaic in figure 3-5.

(1) To begin creating a stereoscopic airphoto mosaic, a suitable base material upon which the mosaic can be stapled must be chosen. Celotex, foam core and "chip board" are all suitable.

(2) Six strips of photography have been used to create the example mosaic (fig. 3-5). Note that photos have been positioned end to end, with about a 10% overlap in each of the strips. Also note that each strip overlaps the adjacent strip by about 30%. The photos not laid down as part of the mosaic are set aside and labeled to show in which strip they belong. These are used for stereoscopic analysis in conjunction with the completed mosaic. It is important to lay out the strip of photos in a way that allows each print number to show, so that the unmounted stereo pair photos that have been set aside can be used in their proper sequence. Since each photo is slightly distorted in scale from the center outward, the trick in laying a stereoscopic photomosaic lies in allowing a very small degree of offset between every photo and strip, so that large offsets are not created toward the periphery of the entire mosaic. Also, by laying out the center strip or two first, with as close a match as possible, any accumulation of offset is thereby forced to the outer edges of the mosaic.

(3) All six strips of photos are laid out loosely in this manner, with weights to hold them in position for a final adjustment. This final adjustment is made by making slight shifts among all the photos to obtain a best match. Then the mosaic can then be stapled fast to the base.

d. *Terrain and environmental factor mapping.* It is not the intent of this chapter to teach photo patterns and corresponding ground conditions for

arctic and subarctic terrain features. A more comprehensive treatment of this aspect of photo analysis can be investigated through the references shown in the Bibliography. The following will discuss the general analysis process, which is described in greater detail in these references.

(1) The stereoscopic mosaic is used in conjunction with a stereoscope and the unmounted alternate (stereo pair) photos of each strip. The exposure numbers on each print are used to locate the proper stereo pair to view a particular area stereoscopically. The entire mosaic can be viewed in the third dimension using this technique.

(2) The process of analyzing and interpreting stereoscopic aerial photography draws upon the background, experience and knowledge of the analyst or, better yet, a team of analysts with knowledge of several disciplines. It is an application of logic and reasoning to synthesize data obtained by observation and inference. It is based on a recognition of natural relationships (physical, biological and cultural) as expressed by key pattern indications present in the image.

(3) A systematic approach to airphoto pattern analysis embodies three phases: first, a regional study; second, a detailed stereoscopic study of pattern elements; and third, a final interpretation of results to answer a posed question or solve a problem.

(a) A regional study, such as has been conducted using the example Landsat image, considers the broad, overall aspects of an area in terms of physical makeup of the landscape; origin, type and distribution of materials; broad natural vegetation assemblages; surface hydrology; and land use patterns. The results of a regional study give a team an overview and assessment of an area in which numerous landscape patterns can be recognized, delineated and associated. The study also serves to suggest areas within the region that might be most suitable for potential site selection and where more detailed study should be undertaken by using larger scale imagery.

(b) A regional study is followed by a de-tailed stereoscopic study of smaller areas selected from the regional analysis. Here each pattern element is systematically studied and evaluated to accurately determine the character of the physical, biological, and cultural components of the landscape. Landforms, surface drainage, depositional and erosional aspects, photographic tones, and biological and cultural aspects are all observed and evaluated as elements of the photo pattern. This detailed analysis, coupled with existing information in the form of published reports, surveys,

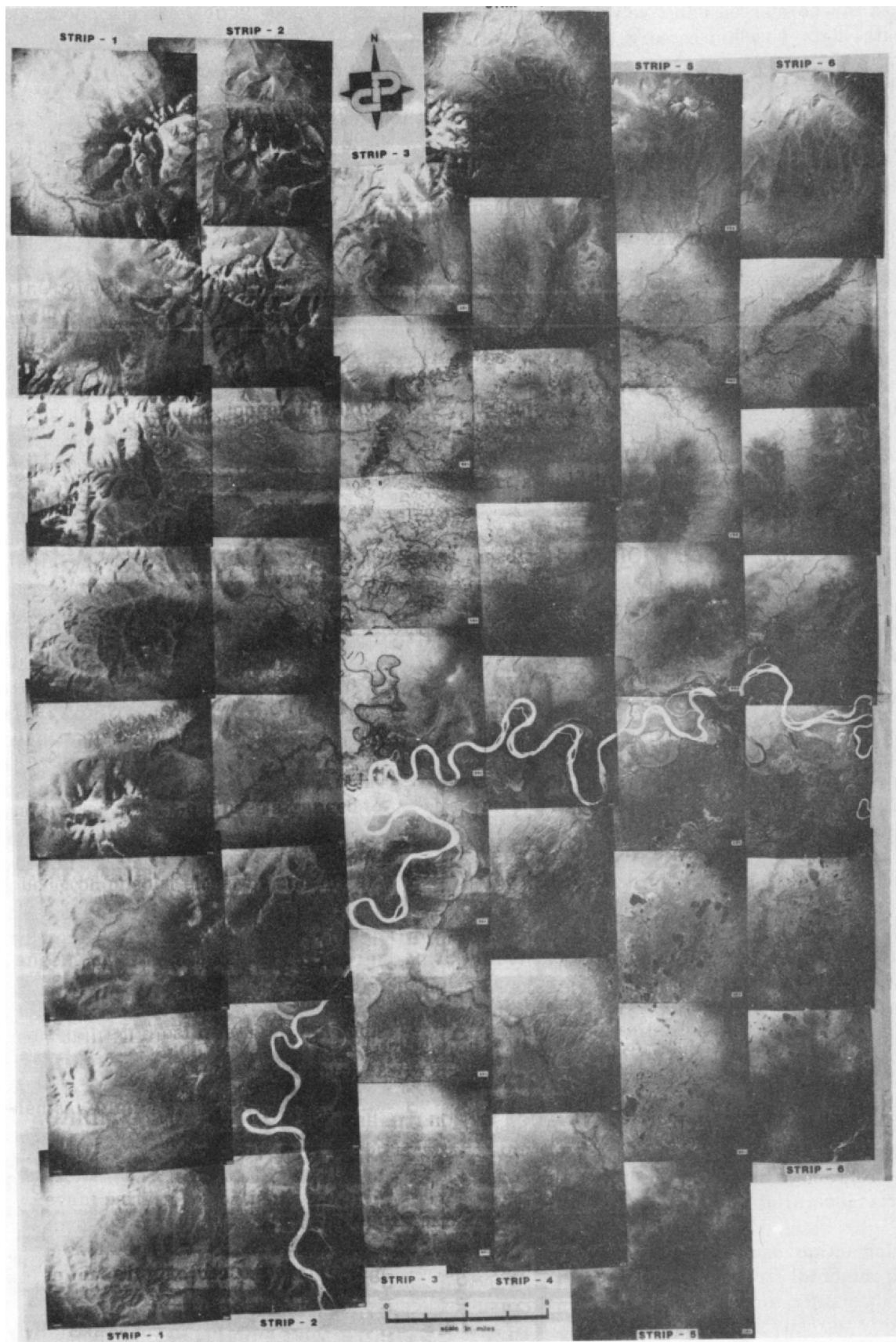


Figure 3-5. Stereoscopic airphoto mosaic.

or maps, can be merged effectively into the "environmental data base" necessary to complete the final interpretive phase of the study.

(c) Upon completion of this second phase of study, the analysis team should consider going into the field to check its work and to iron out any remaining trouble spots. The field correlation of the original photo analysis by the team members is an extremely valuable exercise, which invariably results in an upgrading of individual and team capabilities.

(d) Finally, the interpretive phase of the study is reached where all acquired information is interpreted in the light of a specific problem or question. Only then has enough pertinent information been assembled to warrant the answering of the primary question posed about the study area.

e. *Site evaluation process.* Understanding the relationship between the visible indicators of permafrost and severe frost activity on the aerial photography and actual ground conditions will allow the team to obtain a considerable amount of accurate and detailed information through the photographic analysis process. Detailed stereoscopic study of high quality aerial photos assembled into a stereoscopic photomosaic will result in locating, identifying, and evaluating many of the features necessary to determining ice-soil relationships and the thermal regime. Chief among these are topographic position, parent materials, surface drainage, vegetation, exposure to solar energy, and above all, the well-established indicators related to permafrost and frost action phenomena. Some of these indicators are polygons, button drainage, pingos, frost boils, altoplanation features, solifluction lobes and strips, stone rings, etc.

(1) Airphoto derived information is recorded directly on a series of Mylar or acetate overlays depicting categories such as landforms/soils/rocks, drainage, vegetation and associated wildlife habitat, land use and transportation, and frost/permafrost. These provide an environmental data base and are useful in all stages of project planning and development.

(2) For purposes of locating or siting, the airphoto analysis technique offers much to the location engineer in terms of the following:

—A basis for understanding an area in regard to criteria governing the type of structure to be built.

—Information about likely problems because of the environmental stresses present.

—A basis for predicting environmental impacts likely to result during construction.

In the Arctic these are extremely important because of the often very sensitive thermal regime of the

terrain.

(3) Considerable use can be made of airphotos during the design phases for structures, large installations and transportation systems. However, the designer needs detailed quantitative data such as composition, profile or stratigraphic characteristics, thickness and kind of mantle on bedrock, densities, bearing strength, surface and subsurface moisture, presence and type of frost-susceptible materials, thickness of the active layer, ice/soil relationships in the permanently frozen subsurface, and location and type of organic material, if present. The present state of the art does not permit obtaining quantitative data on any of these items by photo analysis or any other remote sensing means. However, the detailed analytical study of photo patterns will result in mapping the type, distribution, and general characteristics of soils and rocks; determining the complexity and uniformity of a deposit; determining the location and extent of surface water and suspected occurrences of high subsurface moisture; discovering general permafrost location and characteristics; determining the location and general magnitude of frost activity in the active zones; and identifying and locating areas requiring concentrated attention for successful construction. Since the quantitative data can only result from field sampling and laboratory testing, the photos play an important role in planning the field sampling program.

(4) Individual factor overlays are presented that result after the photointerpreter has delineated photo patterns on the airphoto mosaic through the processes of stereoscopic viewing and analysis. Overlays depicting land forms, drainage, surface materials, vegetation, land use, and special factors such as permafrost can all be created separately. Examples of some of these overlays, prepared from the photomosaic (fig. 3-5), are presented as figure 3-6.

(a) *Drainage overlay.* The various patterns of drainage evident on this overlay reflect conditions of the bedrock and surface materials composing the terrain. All of the landform and permafrost boundaries on the following two overlays correspond to changes in the patterns of drainage. This drainage factor tends to be one of the most important factors to be mapped in any photo analysis study. Also, it should be the first factor to be mapped because it forces an analyst or team of analysts to view the entire area stereoscopically to delineate all the fine drainage detail. This, in turn, provides a necessary initial familiarity with the entire area.



Figure 3-6a. Individual factor overlays—Drainage.

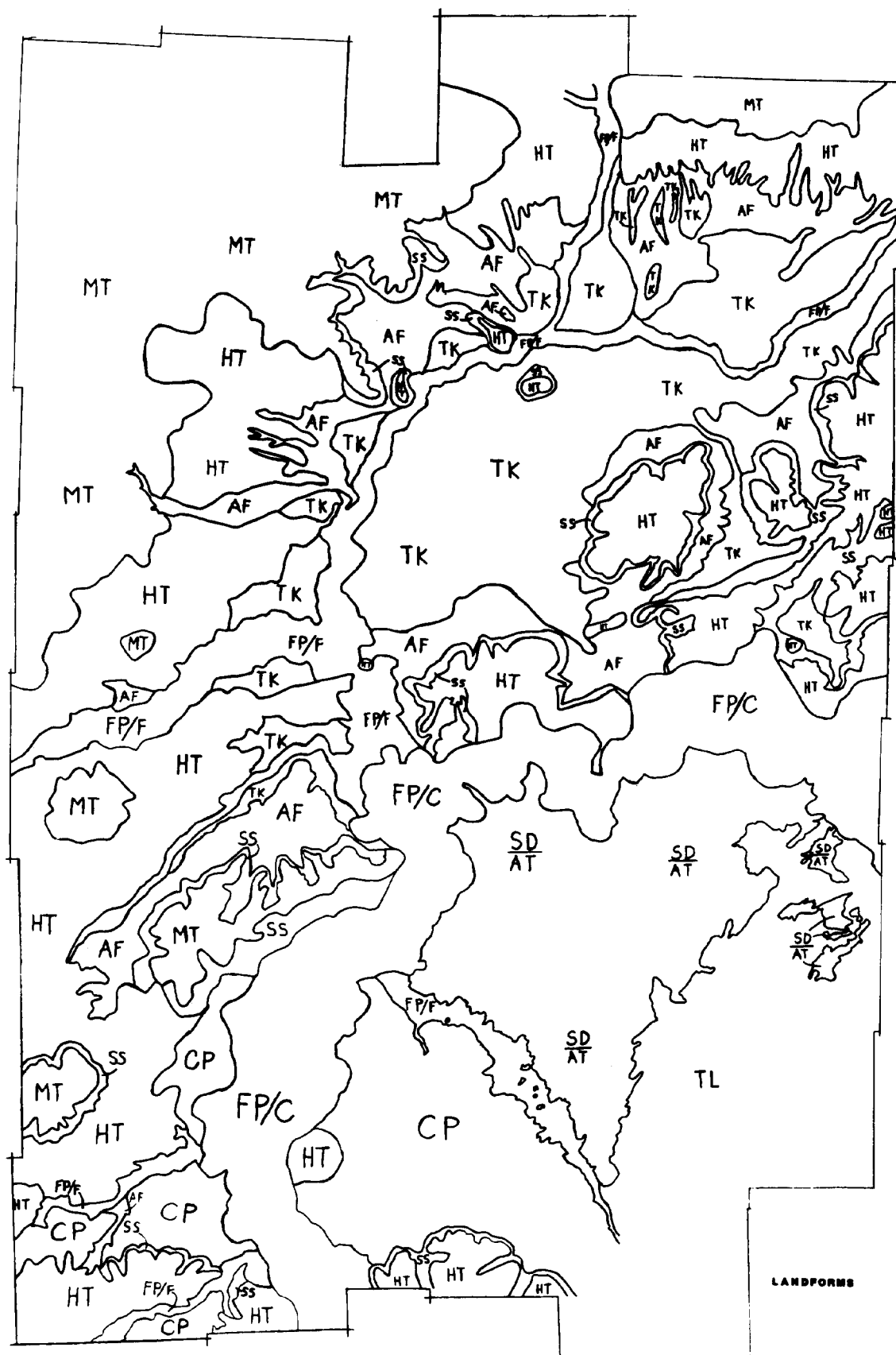


Figure 3-6b. Individual factor overlays—Landforms.

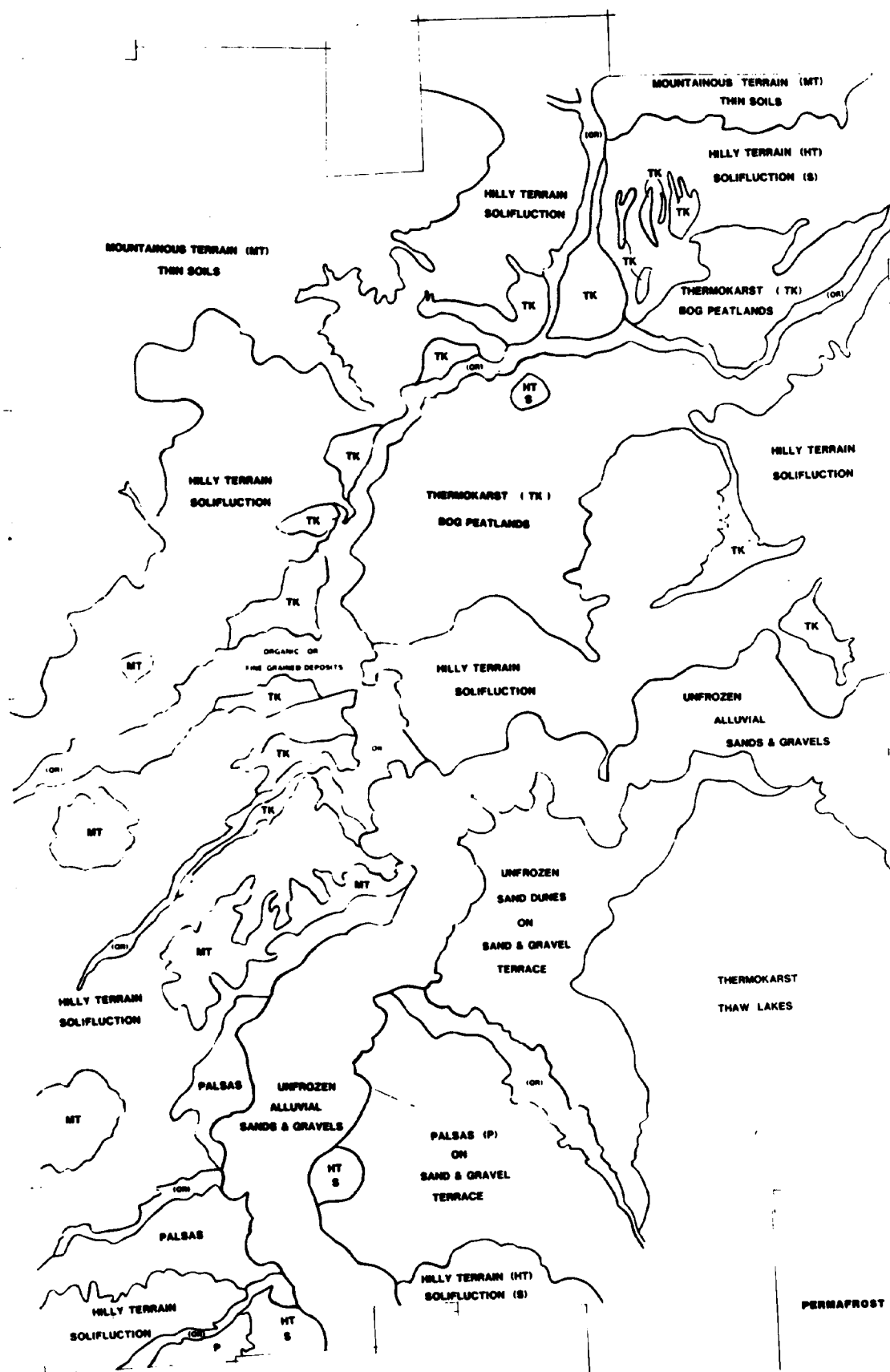


Figure 3-6c. Individual factor overlays—Permafrost.

(b) Landform overlay and engineering materials delineation. The original scale of the photos used to create the stereoscopic photomosaic in figure 3-5 is 1:62,500, or 1 inch to the mile. At this scale, terrain information can be identified and delineated stereoscopically. However, reducing the 40- by 60-inch photomosaic and overlays to fit the format of this publication has caused very fine detail to be eliminated. The mapped features in this example include the following:

—MT (mountainous terrain), which occurs at high elevations, and has a thin soil mantle, with bare rock outcrops.

—HT (hilly terrain), which occupies areas flanking high elevations as ridges or spurs. "Horse tail" drainage can be associated with much of this pattern, which is suggestive of ice-rich silty materials.

—AF (alluvial fans), which are large, valley fill, coalescing fan deposits. Long slopes, flat gradients and "soft"-appearing dissection by surface drainage are indicative of ice-rich silty soils.

—SS (solifluction slopes), which are slopes flanking many of the mountains and larger hill masses composed of unconsolidated deposits, saturated with water released by thawing.

—TK (thermokarst), which occurs here in large, flat, ice-rich areas beyond the terminus of valley fill alluvial fans.

—FP/F (flood-plain/fine-grained deposits), which are ice-rich, silty deposits.

—FP/C (flood-plain/coarse-grained deposits), which are predominantly unfrozen, alluvial sands and gravels.

—TL (thaw lakes), which indicate thermally unstable materials developing into a lake-studded, low-lying planar surface.

—SD/AT (sand dunes lying upon an alluvial terrace), which are unfrozen sand dune deposits lying on a partially frozen alluvial terrace.

—CP (coalesced palsas), which are small hillocks on a planar surface caused by local upheaval of the active layer in a permafrost environment with fine, silty soils.

(c) *Permafrost overlay*. This overlay delineates the permafrost-influenced terrain patterns from the non-permafrost areas. The overlay is more or less self-explanatory. This overlay, coupled with the landform and drainage overlays, would demarcate the alluvial deposits along the major river valley and the sand-dune-covered terrace inside the broad bend of the river as being the most promising areas to investigate on the ground for site selection purposes.

(d) *Vegetation type and distribution overlay*. From the scale of photography used in this example, no definitive identification of vegetation could be done. Special overflights to obtain imagery at scales larger than 1:10,000 would be required to evaluate the biological patterns of the landscape.

(e) *Detailed permafrost features overlay*. Likewise, even to observe the numerous patterns of permafrost (polygons, solifluction lobes, soil stripes, frost boils, etc.), much larger scales of photography have to be used. Only the gross effects of permafrost were observed and used in creating a general permafrost overlay for this example illustration.